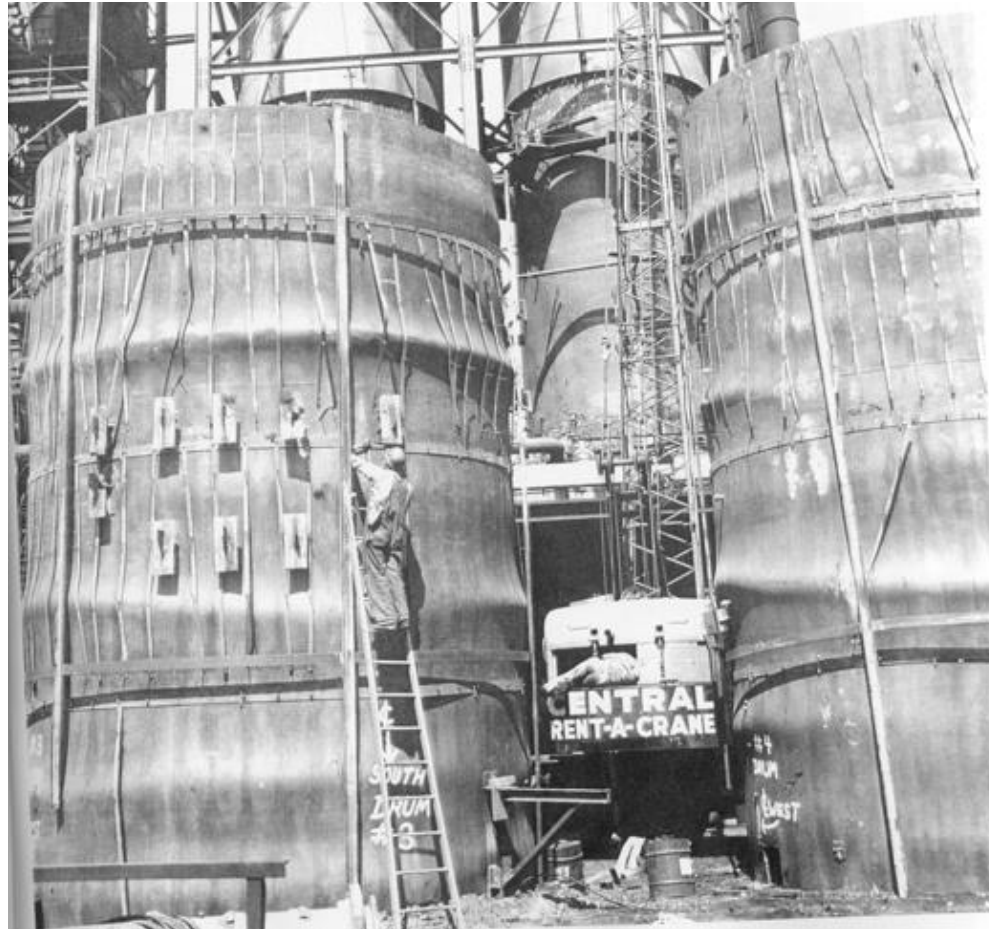


# Bulging Assessment of Coke Drums A State-of-the-Art Review

Mahmod Samman, Ph.D., P.E.  
Houston Engineering Solutions, LLC  
(+1) 832-838-4894  
[mms@hes.us.com](mailto:mms@hes.us.com)

RefComm®  
Buenos Aires 2018

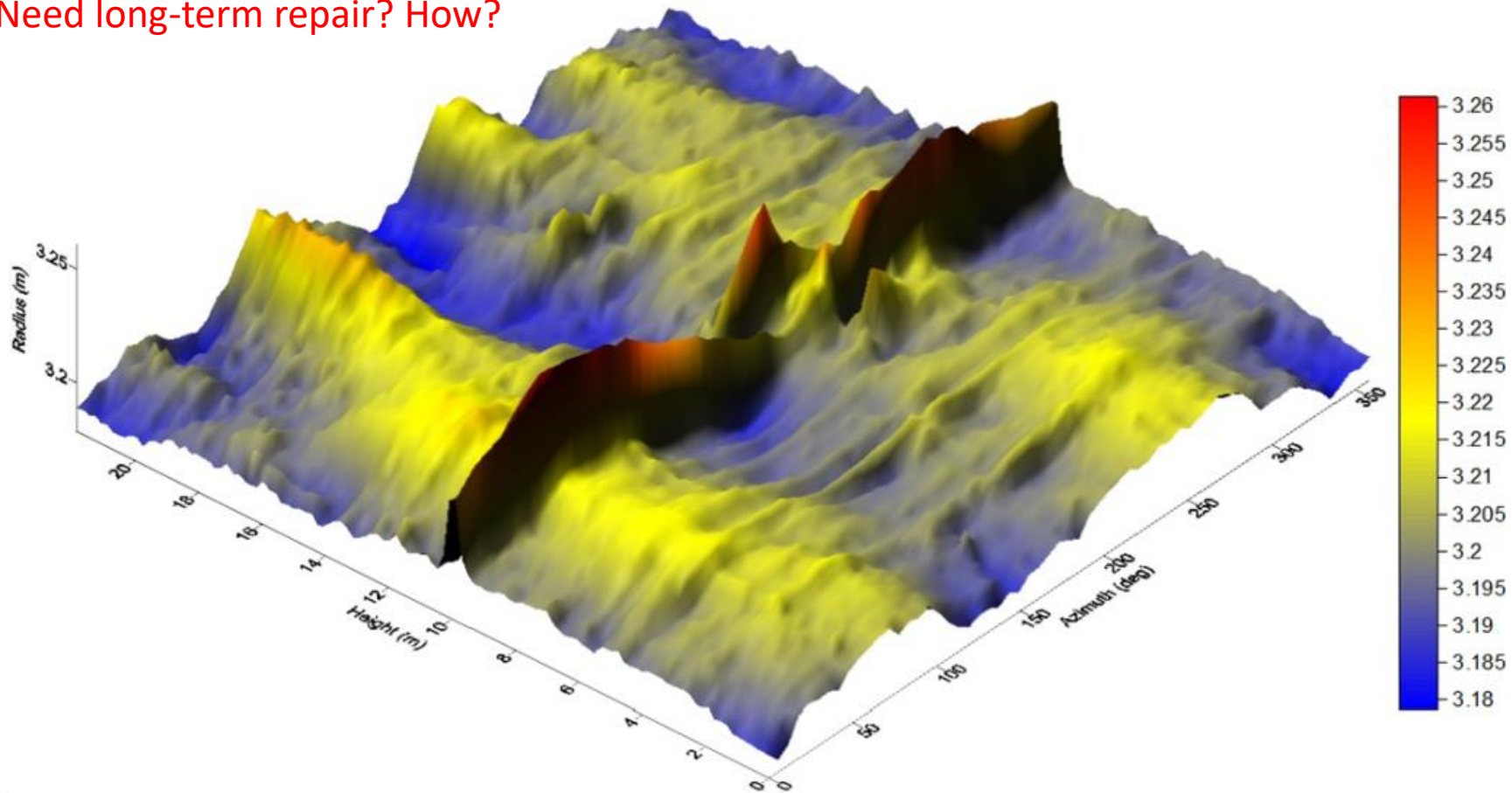
# Coke Drum Bulging



Courtesy of CB&I

# Bulging Assessment

- How bad is bulging?
- Where to expect cracking? Inside/outside?
- When to expect cracking?
- Need long-term repair? How?

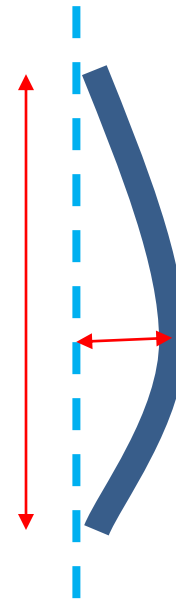


# History

- I. Geometric features 1990-
- II. Stress concentration factors 1996-
- III. API 579/ASME FFS assessment 2001-
- IV. Geometric pattern recognition 2003-2011
- V. Calibrated Plastic Strain Analysis – Plastic Strain Index (PSI): 2011-

# Geometric Features

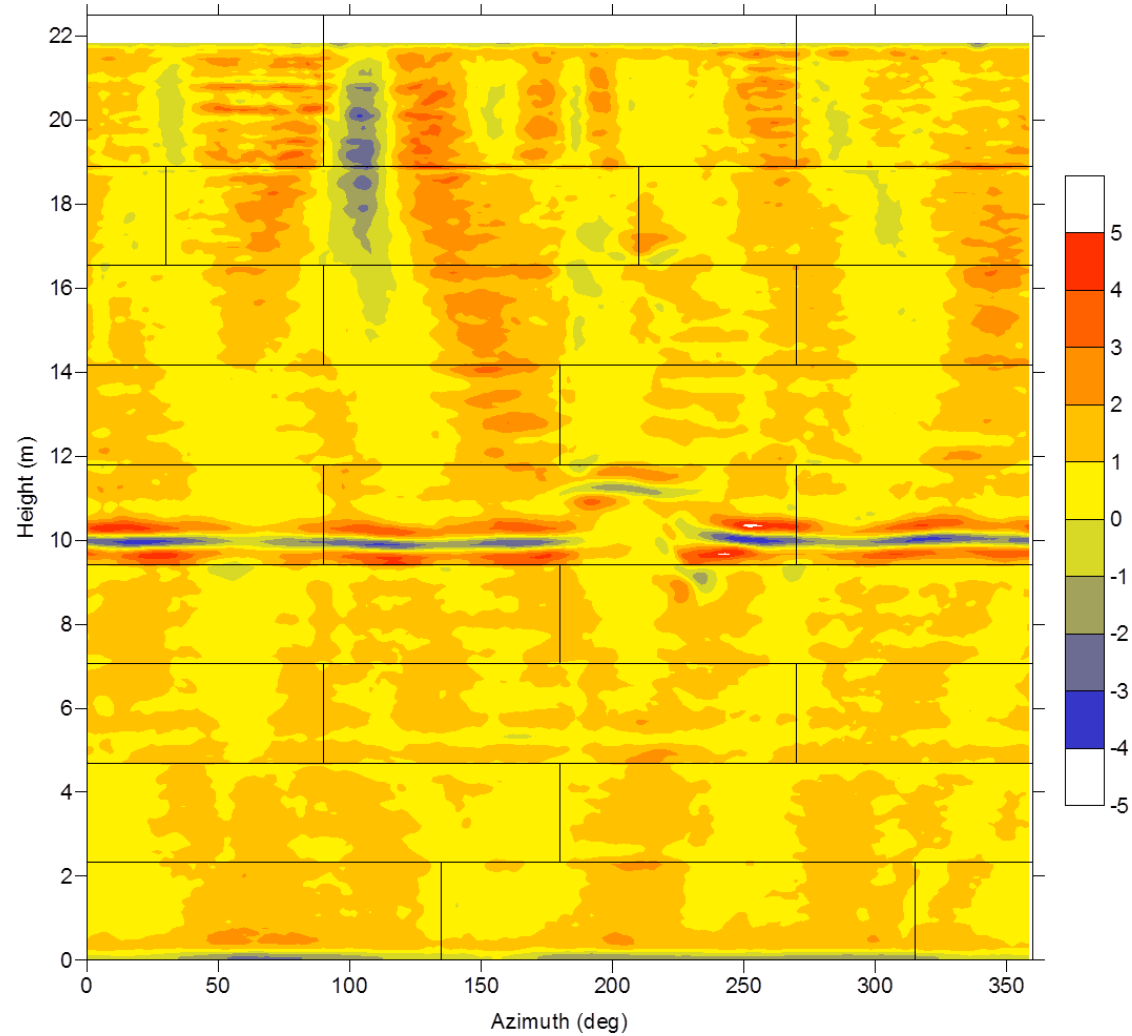
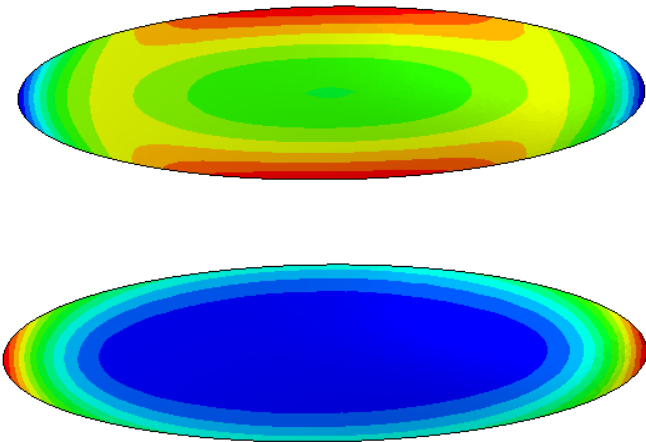
- 1) Bulging magnitude
  - 2) Bulge depth / length
  - 3) Sharpness / derivatives
- Advantages
    - Simple
  - Disadvantages
    - Not based on solid mechanics
    - Do not relate to any industry standard
    - Have not correlated well with observed cracking



# Stress Concentration Analysis

- Linear elastic finite element analysis.
- Drum is built with bulges (no plastic strain).
- Apply design / unit loads.
- Correlates stress intensification to severity.
- Advantages
  - Simple
- Disadvantages
  - Unrealistic model (loads, elastic,..).
  - Susceptible to significant error sources (ovality, bulge size, aspect ratio, etc..).
  - Excludes the primary cause of bulging failure.

# Stress Concentration Analysis



# Bulging Assessment per API-579 / ASME-FFS

- Level 1: N/A to coke drums
  - Fabrication tolerance.
  - Not for cyclic service.
- Level 2: N/A to coke drums
  - Stress analysis criterion removed after 2000 Edition.  
No replacement yet.
- Level 3: Infeasible and costly process
  - Lack of proper load definition.
  - Costly to obtain data and simulate bulging.
  - Never done!



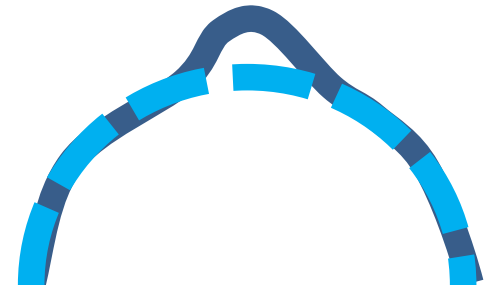
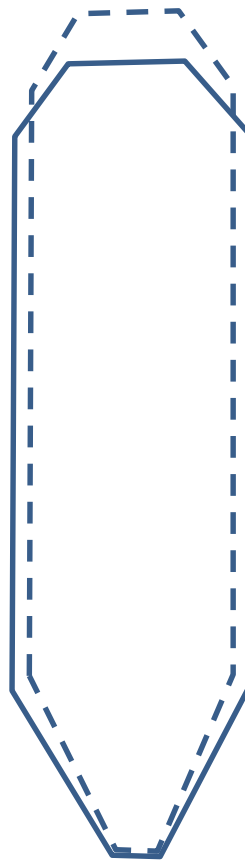
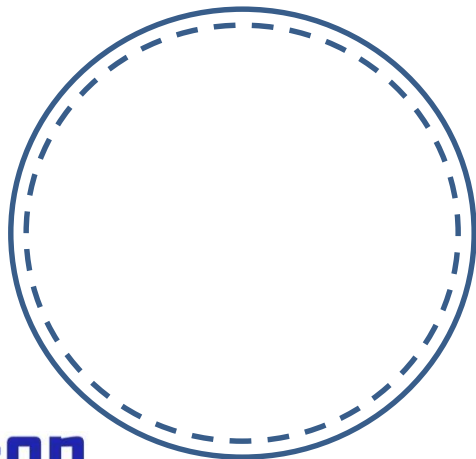
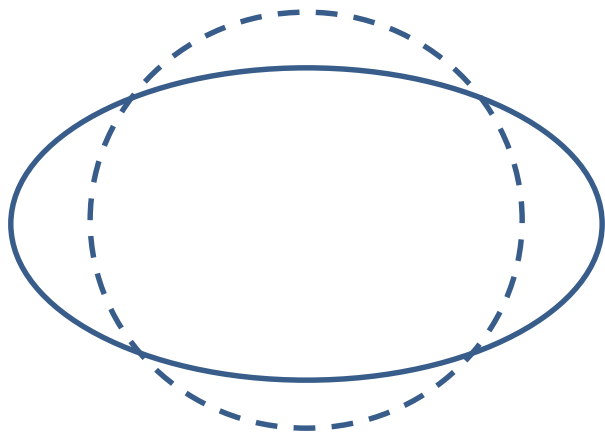
# Geometric Pattern Recognition

- Database of cracking history.
- Identification of geometric features associated with cracks.
- Commercially unavailable
- Advantages:
  - Excellent correlation with cracking.
- Disadvantages:
  - No basis in mechanics.

# Calibrated Plastic Strain Analysis

Local and global distortions

Calibrated using actual failures

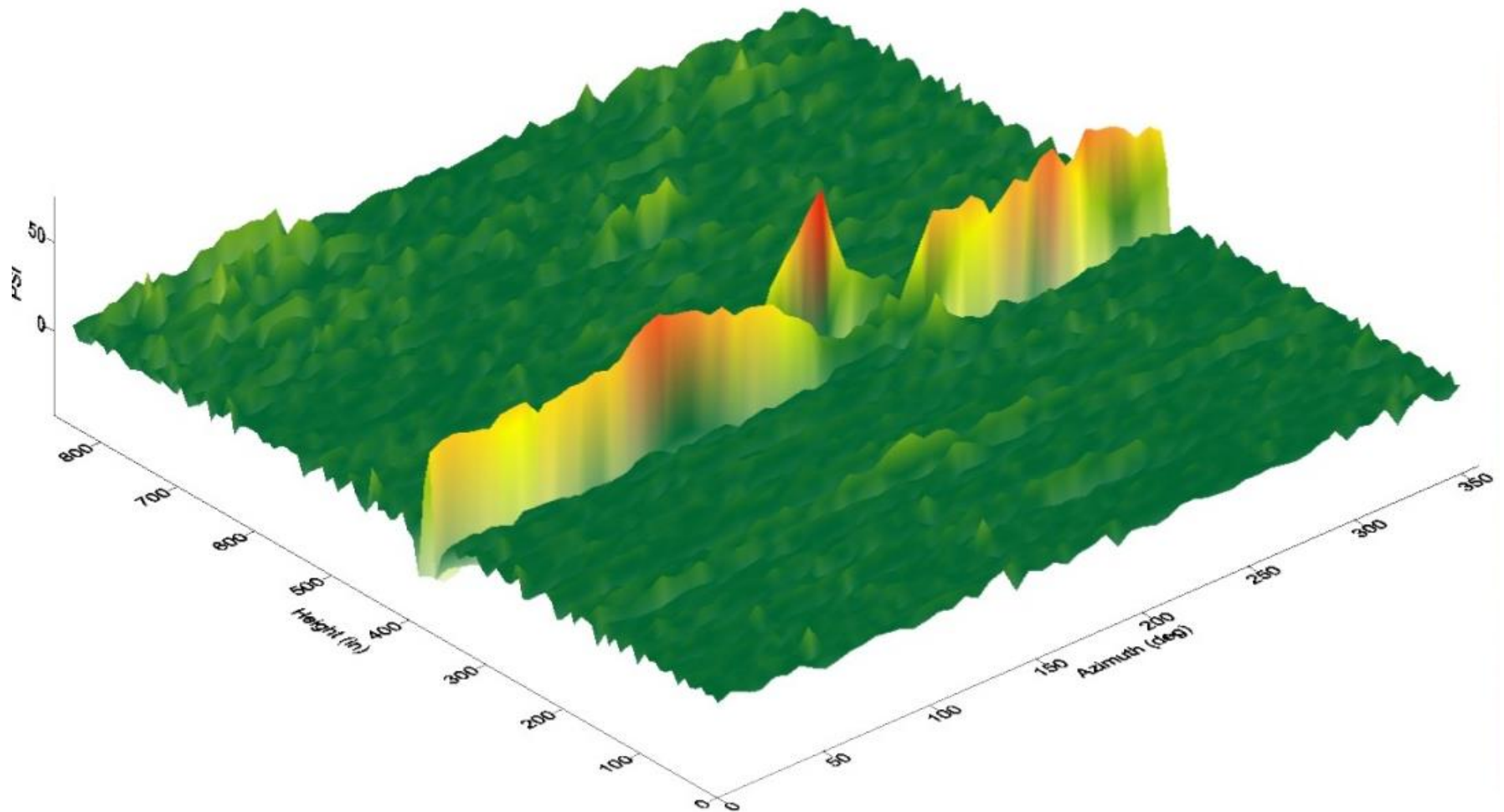


# Plastic Strain Index (PSI)<sup>TM</sup>

- Ratio of effective plastic strain to failure limit of API 579/ ASME FFS Standard.
- Calibrated using database of actual failures
- Excellent correlation with bulging-induced cracks.
- 300 assessments.

<b>PSI magnitude</b>	<b>Severity Grade</b>	<b>Likelihood of Bulging-Induced Cracks</b>	<b>Recommended Frequency of Laser Scanning</b>
80% to 100%	<b>Failure</b>	Likely	6 months to 1 year
60% to 80%	<b>Danger</b>	Probable	1 year
40% to 60%	<b>Concern</b>	Possible	1 to 2 years
0 to 40%	<b>Design</b>	Unlikely	2 to 3 years

# Plastic Strain Index (PSI)<sup>TM</sup>



# Comparison

<b>Comparison of Bulging Assessment Methods</b>	<b>Geometric Features (magnitude, derivatives, sharpness, etc.)</b>	<b>Stress Concentration</b>	<b>Full API 579 Procedure</b>	<b>Pattern Recognition</b>	<b>PSI</b>
Based on laws of solid mechanics	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>YES</b>
Uses API 579 industry standard limits	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>NO</b>	<b>YES</b>
Uses realistic thermomechanical loads	N/A *	<b>NO</b>	<b>NO</b>	N/A *	N/A *
Calibrated using database of both external and internal failures	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>
Assessment specifies external versus internal failure initiation	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>YES</b>	<b>YES</b>
Correlation to observed failures published by operating companies	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>
Effectiveness of bulge repairs published by operating companies	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>

\* N/A: Not Applicable

# Where Do We Stand?

## CAN

- Determine likelihood of bulging-induced cracks
- Determine optimal laser scanning interval
- Determine need for long-term repairs

## CANNOT

- Determine likelihood of weld-related cracks
- Predict bulging initiation time
- Predict bulging initiation location
- Predict bulging growth

# RECAP

- I. Geometric features 1990-
- II. Stress concentration factors 1996-
- III. API 579/ASME FFS assessment 2001-
- IV. Geometric pattern recognition 2003-2011
- V. Calibrated Plastic Strain Analysis – Plastic Strain Index (PSI): 2011-